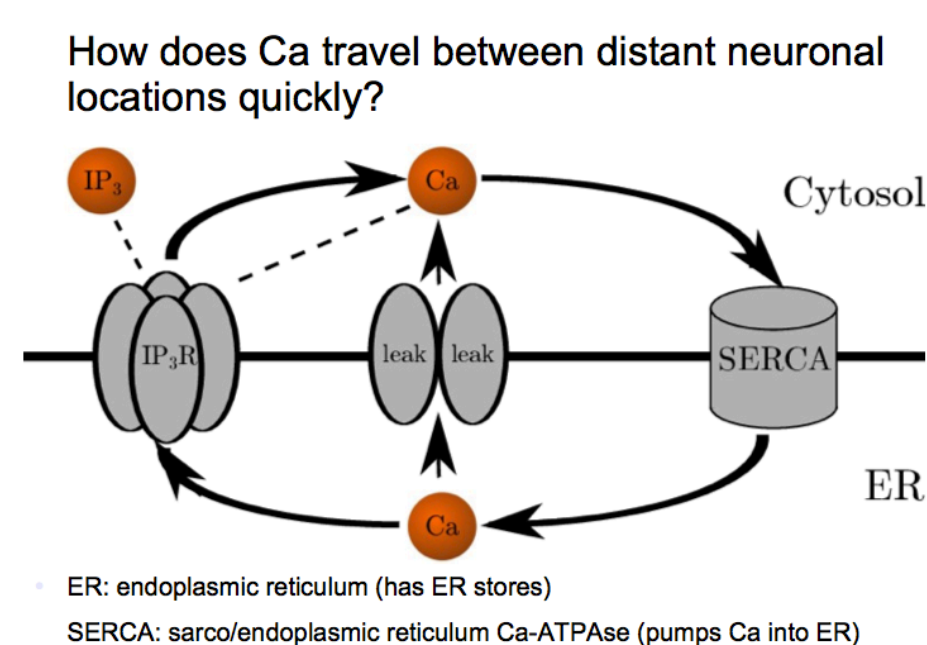


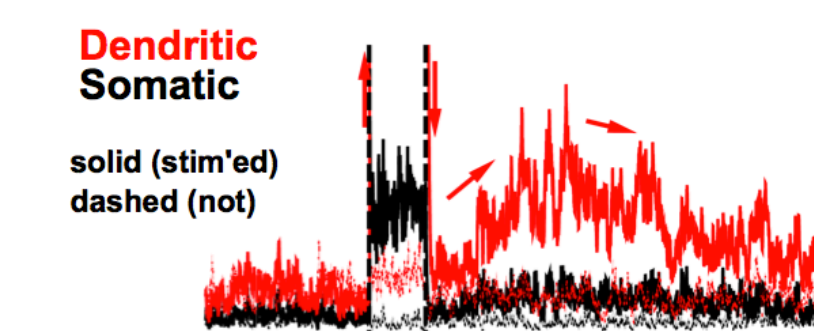
Our Unique Capabilities

We develop empirically-derived models to link the different spatial and temporal scale in the brain. These include reaction-diffusion models of molecular dynamics, hybrid networks with multi-compartment and event-driven neurons, neural field models, and high-level probabilistic models.

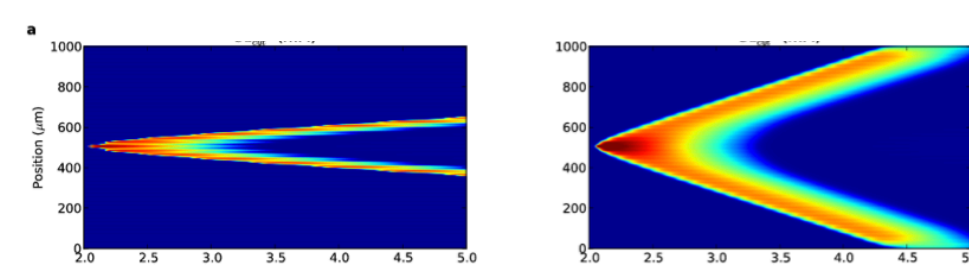
Below: Simulated relations of molecular, cellular, and network dynamics in a model of prefrontal cortex.



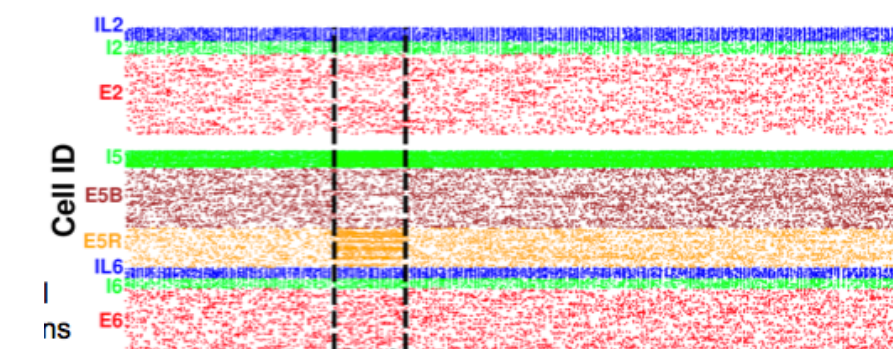
Intracellular dynamics: calcium interactions support persistent activity associated with working memory.



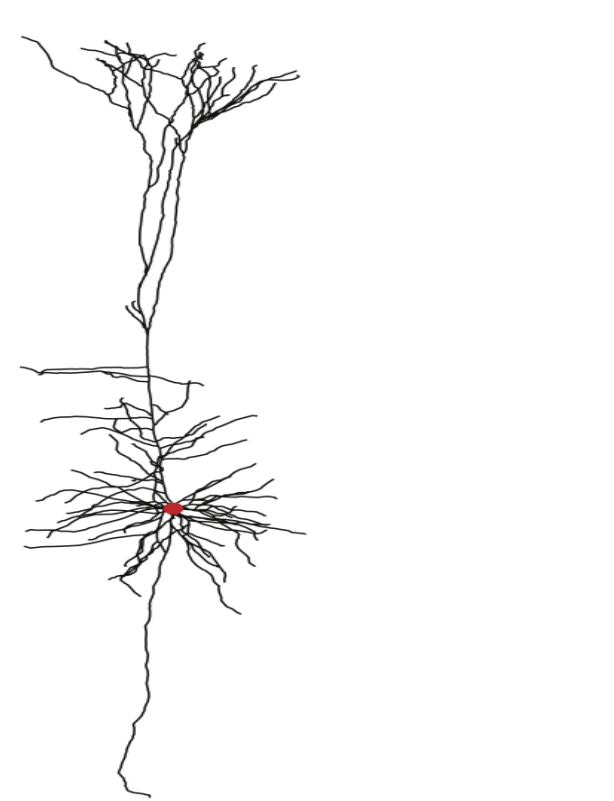
Reaction-diffusion model of CA wave (sub-cellular)



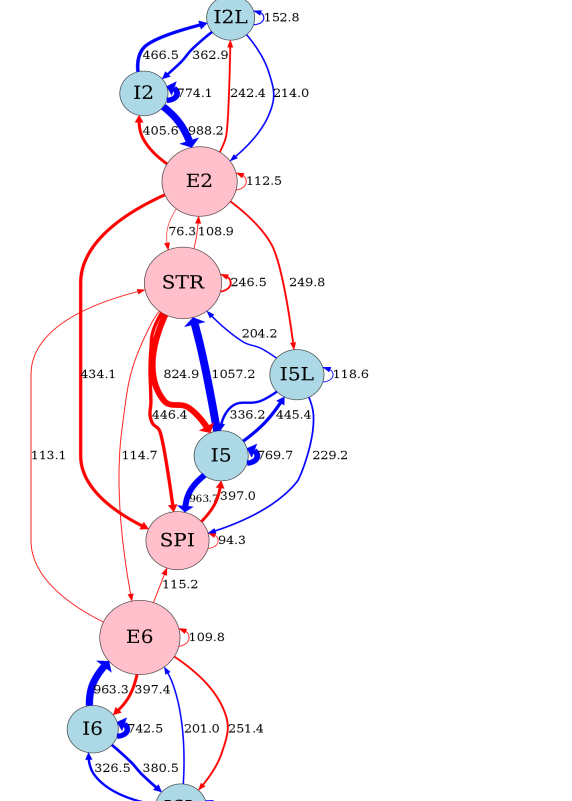
Network effects: persistent activity in layer 5



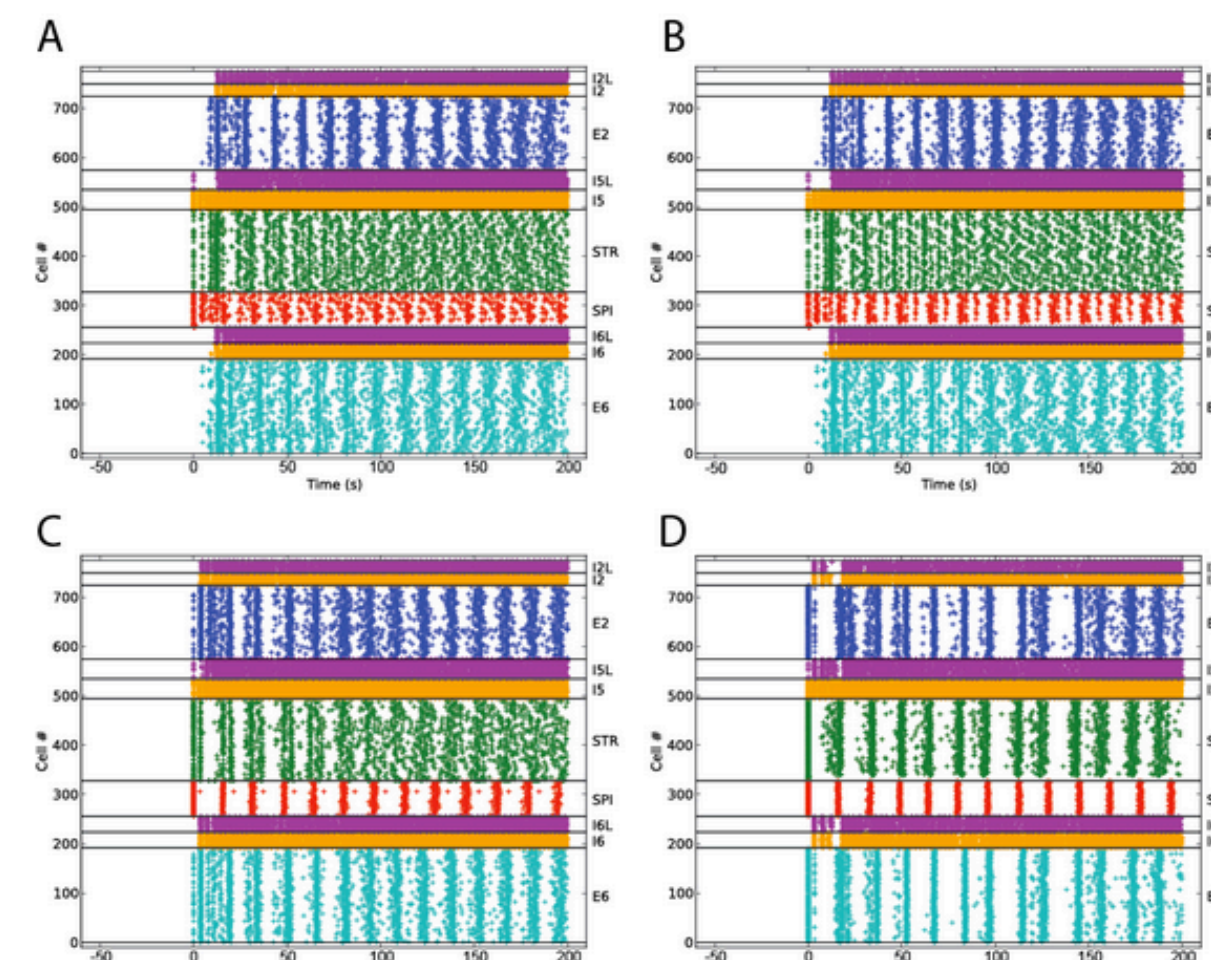
Below: A hybrid network model (multicompartment and event-driven cells) based on detailed cortical microcircuitry of mouse M1 that reproduces experimental firing rates, physiological oscillations, and coincidence-detection.



Morphologically realistic multicompartment cell model of M1 layer 5

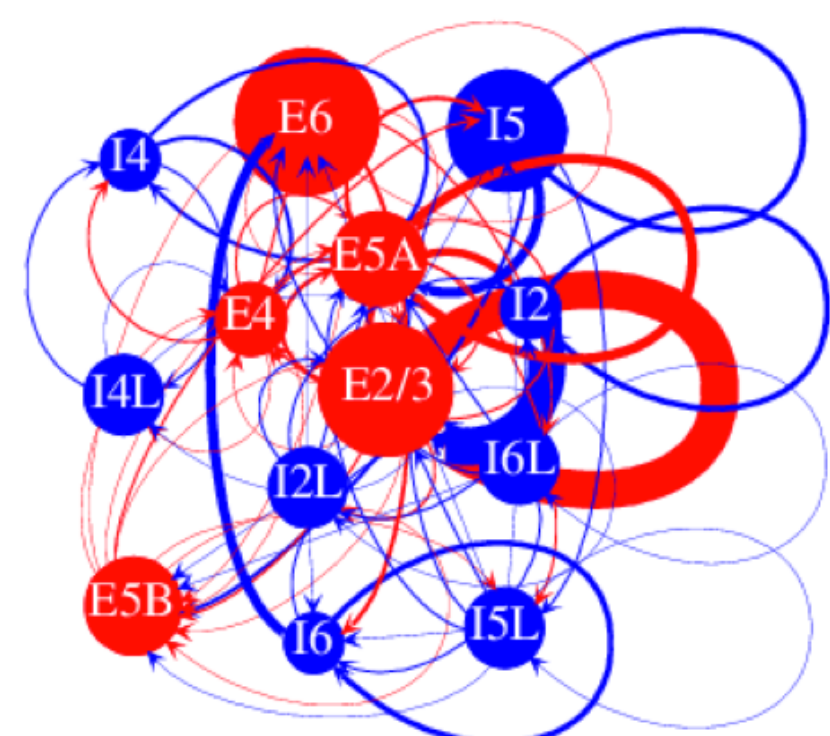


Experimentally-derived connectivity of model of M1 microcircuitry

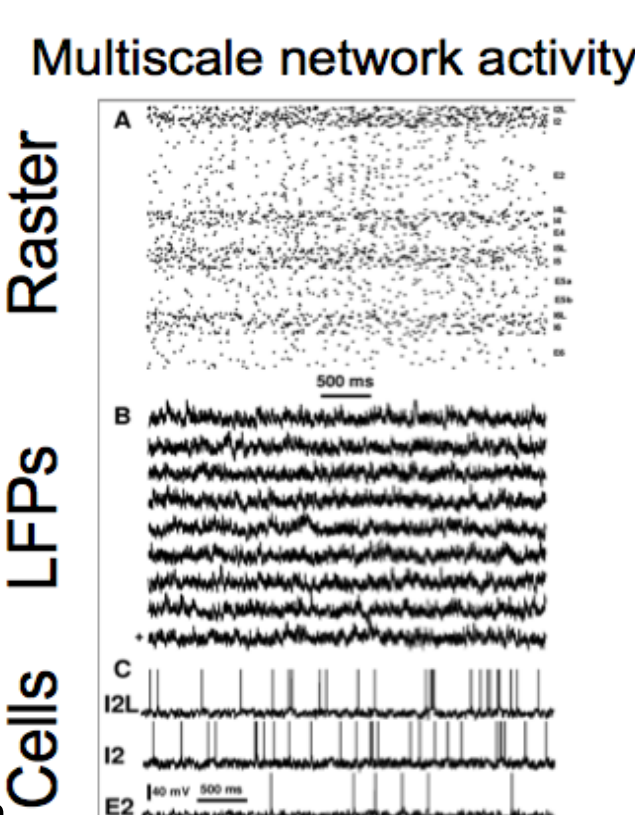


Model-generated raster plot reproducing physiological properties of M1

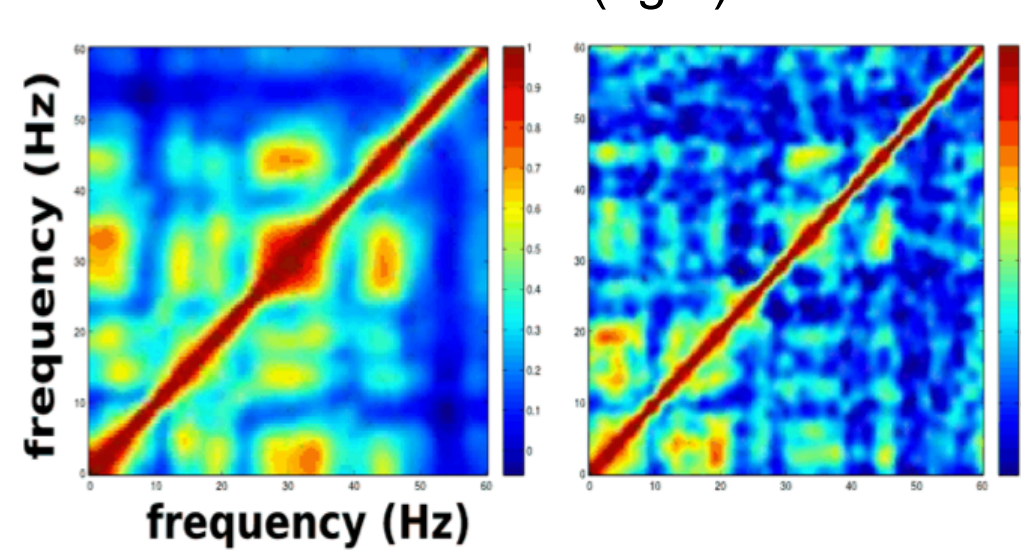
Below: A spiking network model of neocortex that reproduces physiological measures at different scales: cell voltages, raster plots, LFPs, and cross-frequency coupling.



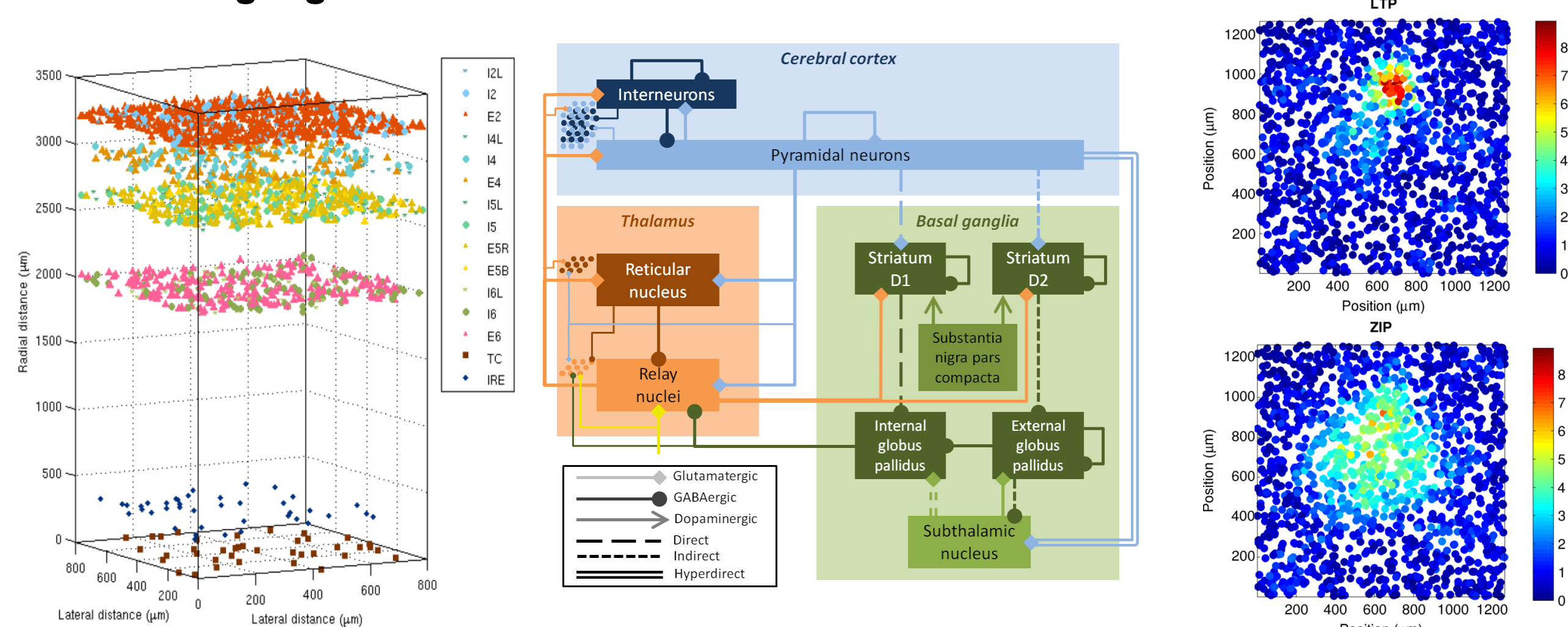
Neocortex model connectivity diagram



Cross-frequency coupling from LFP of rat (prefrontal cortex): experiment (left) vs. simulation (right)



Below: S1 model accurately reproduce physiological properties observed in vivo, including firing rates, local field potentials, oscillations, traveling waves, and learning of tactile stimulus fields. The model has also been integrated with a neural field model of the basal ganglia to model the effects of Parkinson's disease.



Seeking for

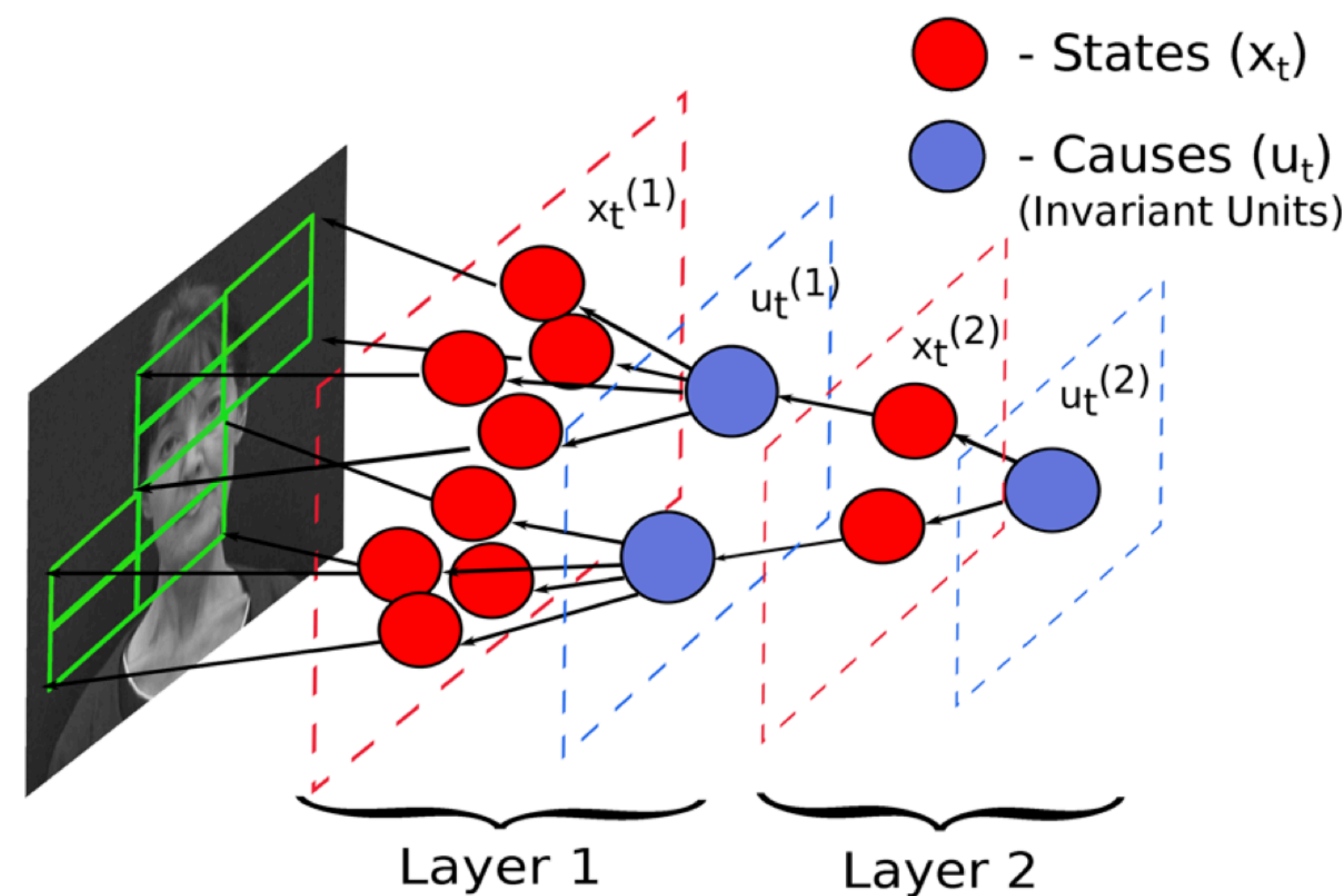
- Additional group to extract machine learning principles from biomimetic computational models.
- Additional group to record high-resolution data from cortical microcircuits.
- Team that requires biomimetic multiscale computational models and algorithmic framework of information processing in the brain.

Research Areas of Interest

We aim to build computational models that map the novel 'cognitive architecture' described below onto the known anatomy and physiology of brain circuitry.

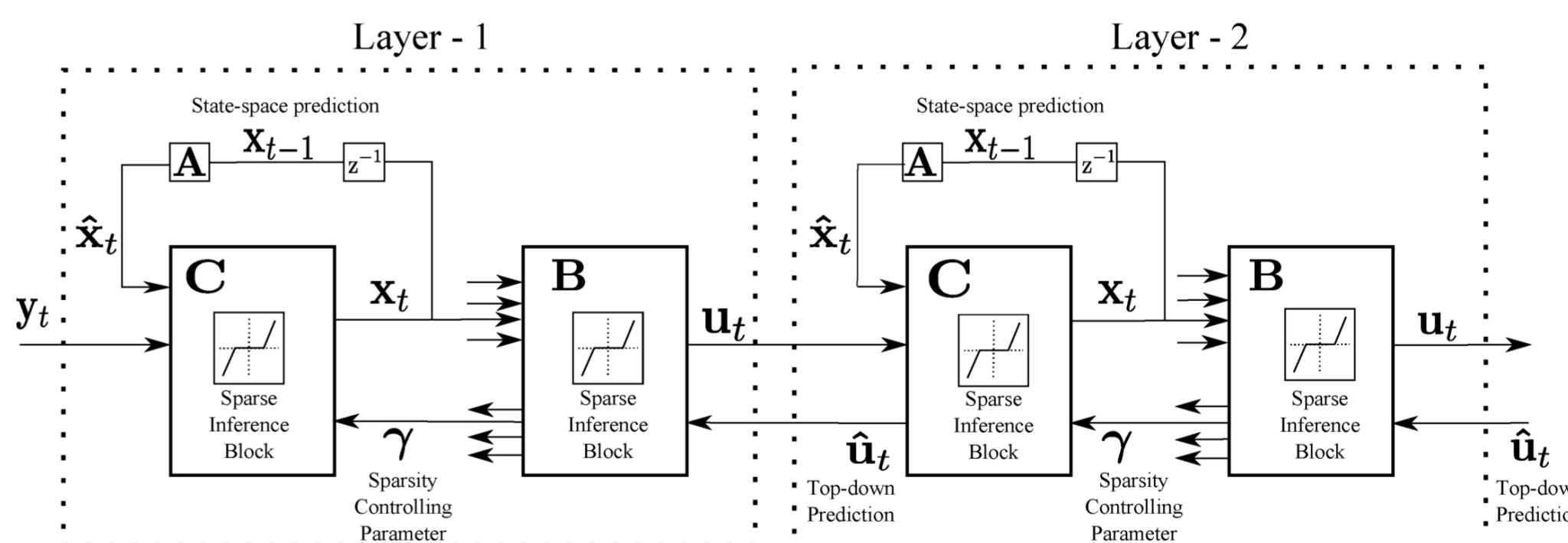
We propose a Bayesian approach to sensory processing, using a hierarchical, distributed architecture of dynamic processing elements. Key features:

- 1) bidirectional (top-down and bottom-up) processing enable perceptual inference using both sensory data and empirical beliefs about causes from higher layers;
- 2) dynamic components are at the core of the model, allowing beliefs about temporal context to influence perceptual inference;
- 3) only salient features of the input data are stored, forming a compressed and sparse representation;
- 4) re-utilization of same model within and across layers is reminiscent of cortical microcircuits, and allows for efficient software/hardware implementation



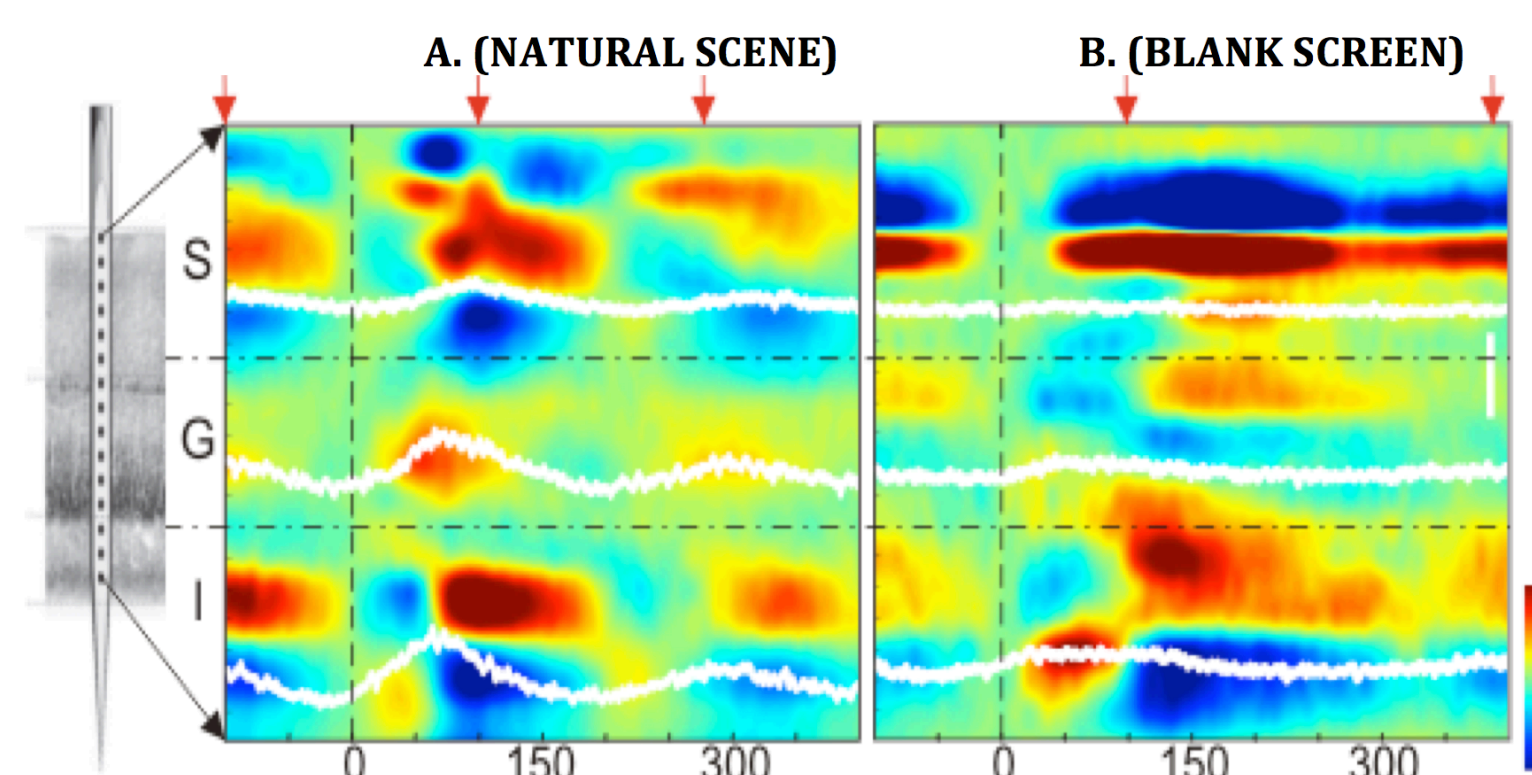
Two-layer hierarchical network illustrating structure of proposed architecture

- Each node consists of two modules: a state-space model, which extracted features, and an invariance-learning model, which inferred causes by pooling over states.
- Inference and parameter learning correspond to minimizing the same energy function with respect to either the states or the causes.
- The model showed better classification by leveraging temporal and top-down contextual information during inference, and was able to disambiguate a synthetic video from correlated noise.



Block diagram showing the flow of bottom-up and top-down information in the proposed architecture.

- We incorporate a key biological feature utilized by the visual system: eye movement control (active sensing). We conceptualize visual parsing and object identification as a continuous loop where a saccade marks the onset of a new sampling episode.
- We propose using a multi-level, multi-method approach (single cell, CSD, LFP, fMRI), to test the model predictions, by characterizing the spatial and temporal dynamics of these interactive processes, and inform and constrain computational modeling.



Laminar CSD profiles from V1 awake monkey during free-viewing task; red arrows indicate activity peaks between saccades to help visualize saccade-related dynamics

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